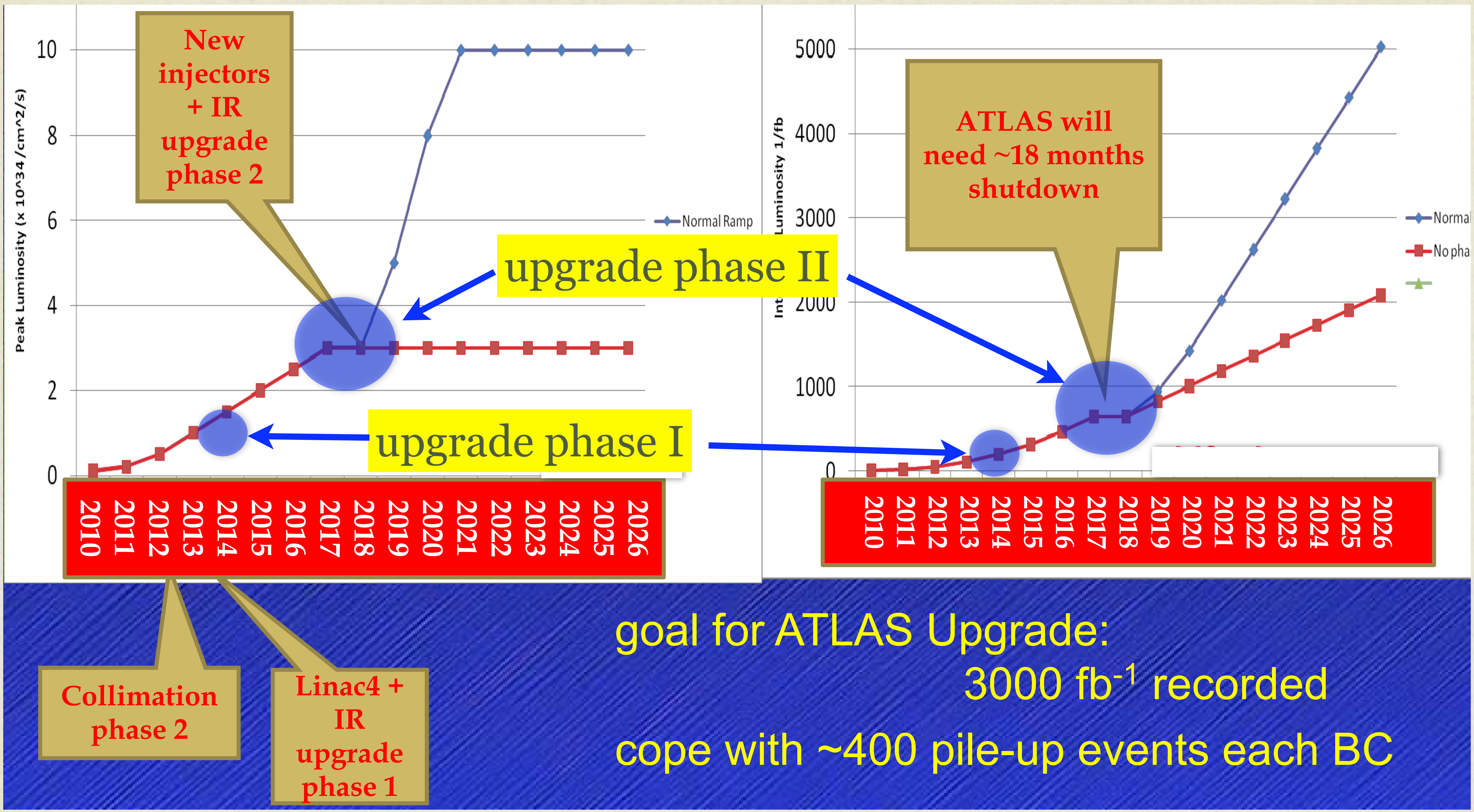
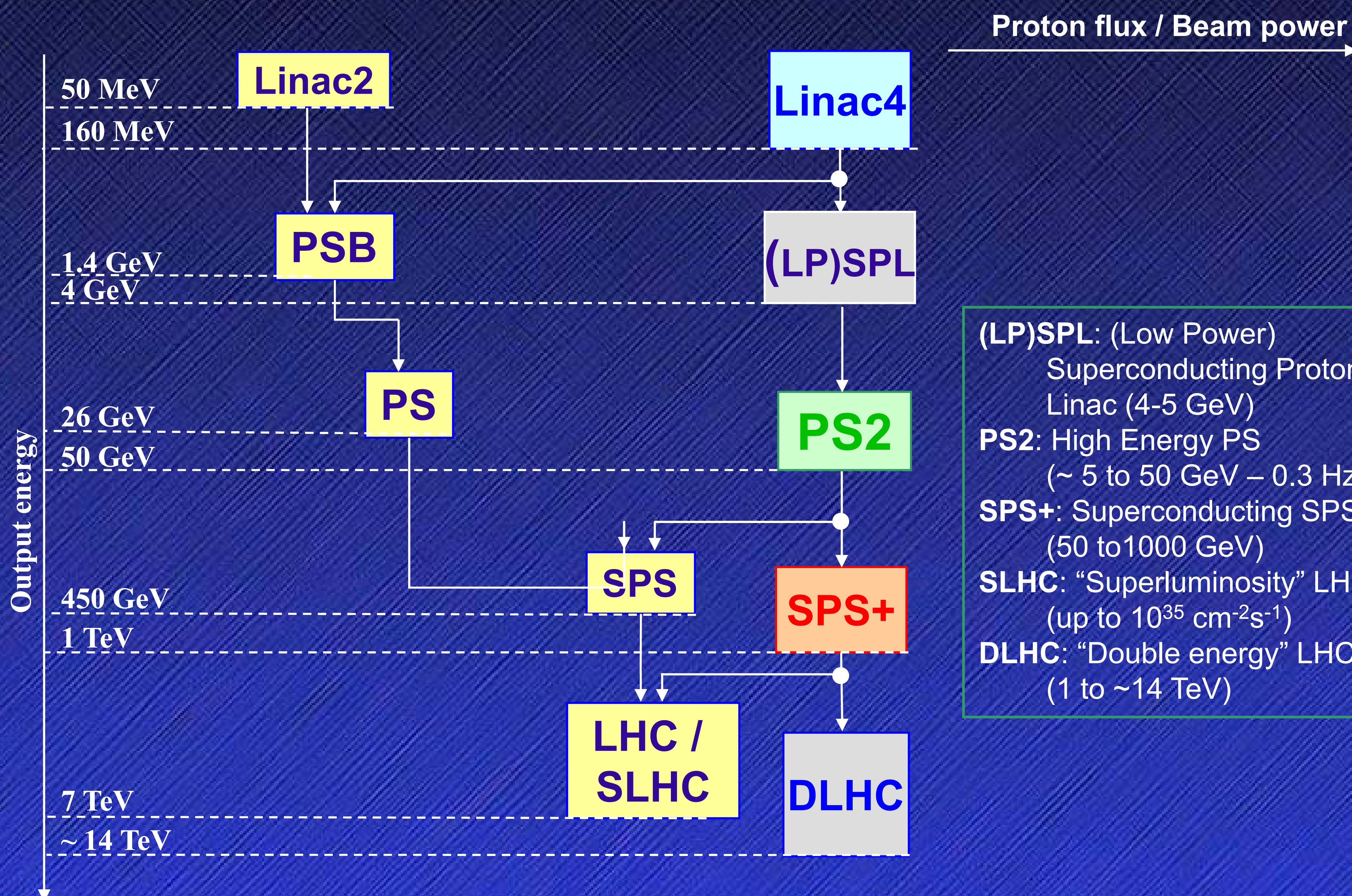
SLHCに向けての（ATLAS）検出器アップグレード

花垣和則（大阪大学）

予想（期待）されるルミノシティ



present and future injectors



(LP)SPL: (Low Power) Superconducting Proton Linac (4-5 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
SPS+: Superconducting SPS (50 to1000 GeV)
SLHC: "Superluminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)
DLHC: "Double energy" LHC (1 to ~14 TeV)

Roland Garoby, LHCC 1July '08

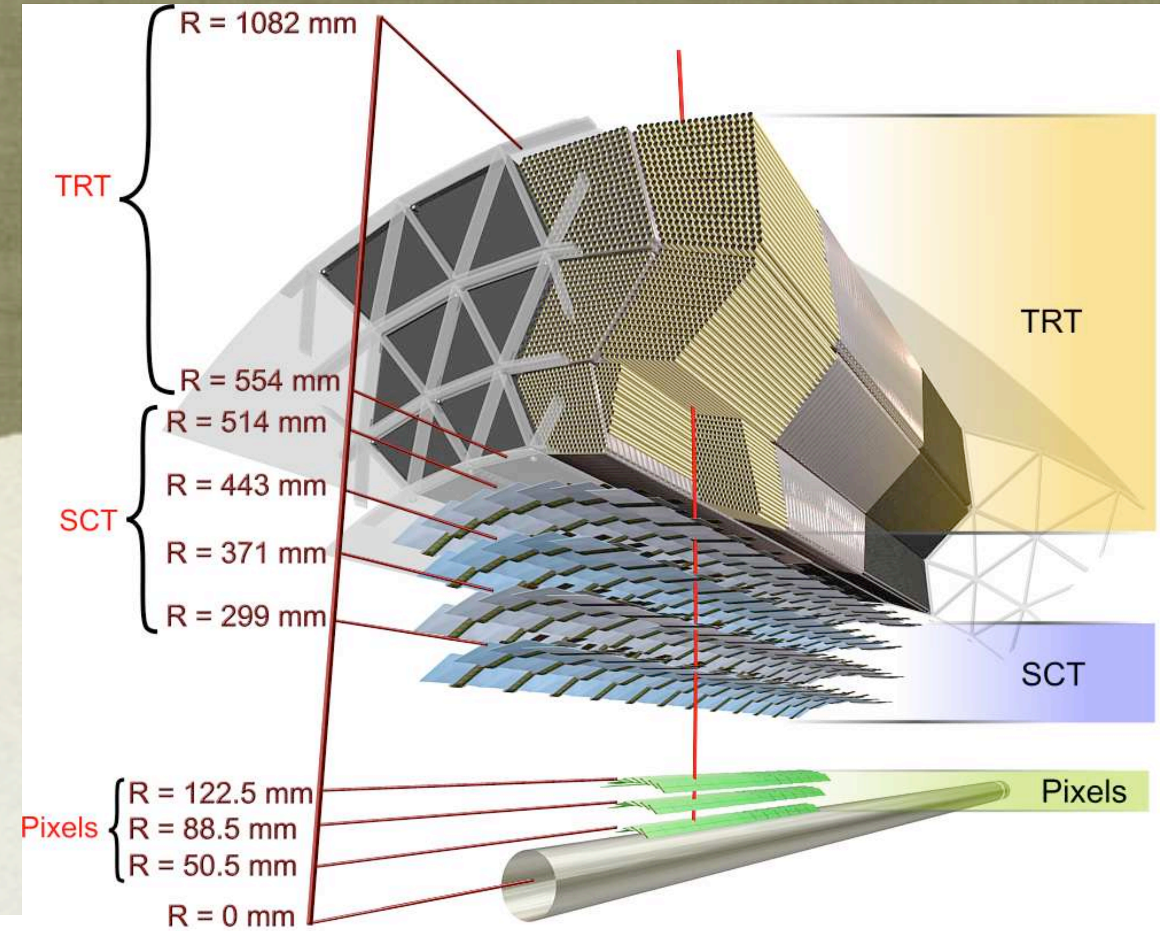
PHYSICS CASE

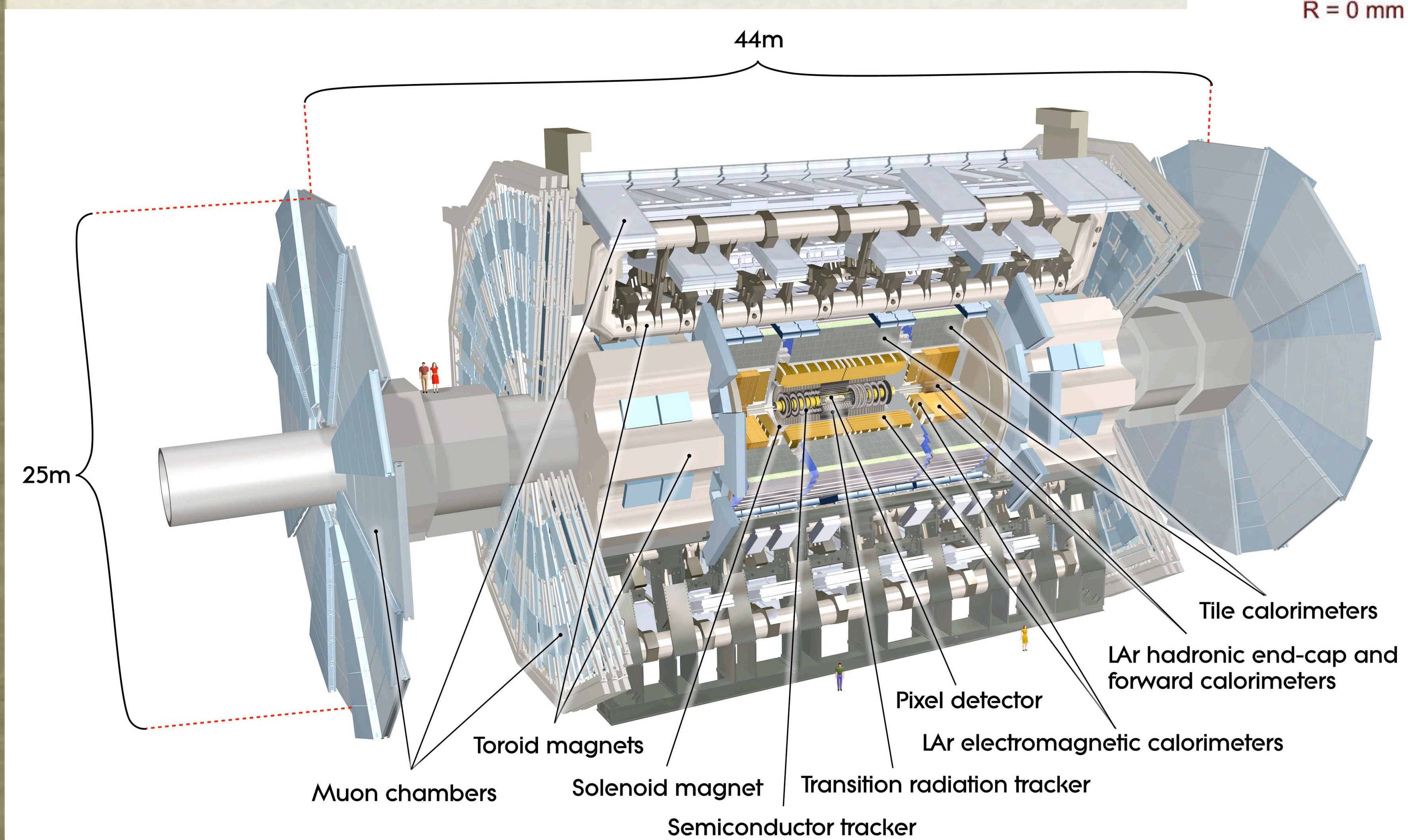
- ヒッグス
  - self coupling ？
  - Y_t, Y_b?

- 超対称性その他

Process	LHC 14 TeV 100 fb^{-1}	SLHC 14 TeV 1000 fb^{-1}	DLHC 28 TeV 100 fb^{-1}	LC 0.8 TeV 500 fb^{-1}	CLIC 5 TeV 1000 fb^{-1}
Squarks (TeV)	2.5	3	4	0.4	2.5
$W_L W_L$ (σ)	2	4	4.5	6	90
Z′ (TeV)	5	6	8	$8^{\perp}$	$30^{\perp}$
Extra-dimens. scale (TeV)	9	12	15	$5–8.5^{\perp}$	$30–55^{\perp}$
q* (TeV)	6.5	7.5	9.5	0.8	5
Compositeness scale (TeV)	30	40	40	100	400
TGC, λ_γ (95%CL)	0.0014	0.0006	0.0008	0.0004	0.00008

ATLAS 検出器


R = 1082 mm
TRT
R = 554 mm
R = 514 mm
R = 443 mm
SCT
R = 371 mm
R = 299 mm
R = 122.5 mm
Pixels
R = 88.5 mm
R = 50.5 mm
R = 0 mm
TRT
SCT
Pixels


44m
25m
Tile calorimeters
LAr hadronic end-cap and
forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Muon chambers
Solenoid magnet
Transition radiation tracker
Semiconductor tracker

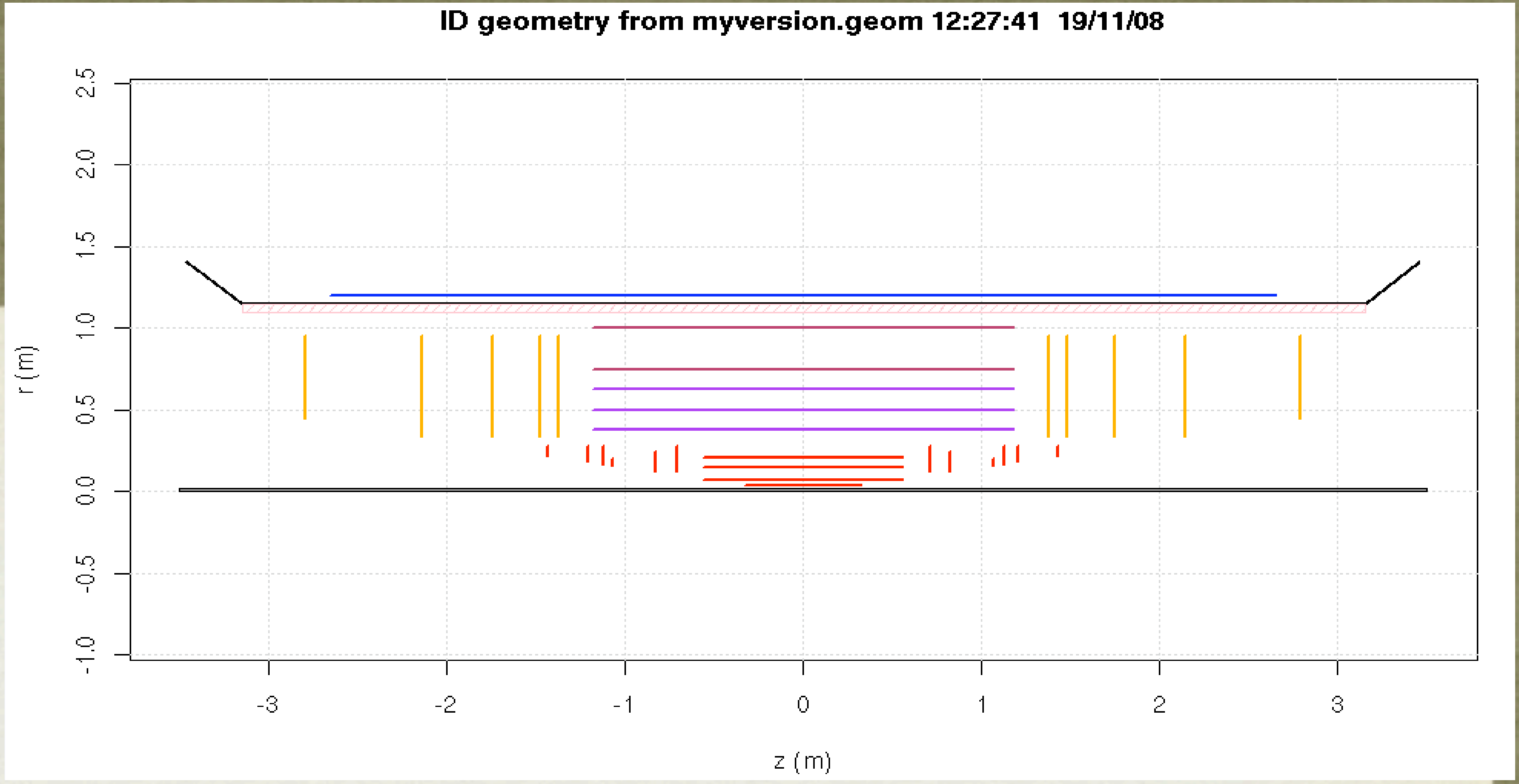
PHASE I

- 基本的には、ATLAS, CMSともに(最内層の)Pixelが死んでしまうので、それに対する対策
  - 300-400 fb^{-1}まではOK
- シャットダウンは6－8ヶ月間（2014?）
  - ATLASは交換に時間がかかるので、ビームパイプを細い物に交換し、パイプと現存する検出器の間に1層だけ加える（Insertable B Layer, IBL)
  - CMSはpixelを全部交換
- ルミノシティは 3 x 10^{34}（現行のデザインは 1 x 10^{34}）
  - TriggerとDAQは少しいじるが、他は変更無し

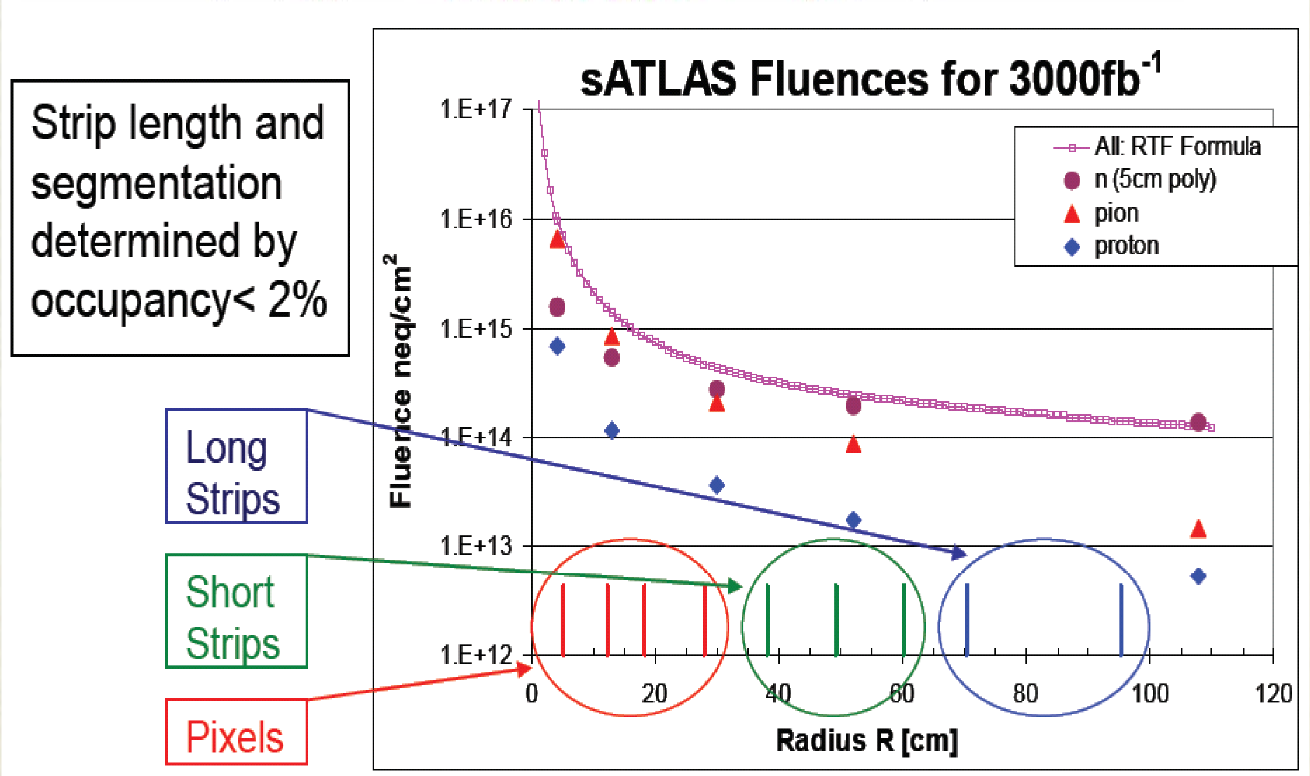
PHASE II -- 所謂 SUPER LHC

- 2017-18が今のところの予定
  - 1年遅らすかどうか議論中
- ルミノシティ 1 x 10^{35}（テクノロジーは議論中）
  - Bunch crossing あたり ~400 の衝突
- ATLASの主な変更点
  - Tracker 全部を交換、プラスbeam pipe
  - Barrel calorimeter は electronics/readout の変更
  - Forward calorimeter は一部交換
  - Forward muon chamber もたぶん交換
  - トリガーとDAQ

TRACKER



- All silicon
  - 4 layers of pixel,
    3 short and 2 long strips
  - Layout optimization on going ⇐ Long strip may have too high occupancy



TRACKER

- Sensor
  - Many technology choice for pixel
    - Needs to survive up to a few 10^{16} n_{eq}/cm^2
    - 3D, Diamond, planar n-in-n, n-in-p, etc.
  - Probably n-strip in p-bulk for strip
- ASIC for readout
  - Prototyping on going for both pixel and strip
- Hybrid/Stave design under consideration
- Cooling
  - CO_2?
- Powering
  - Serial or DC-DC?

CALORIMETER

- Detector itself should be OK, except for forward Liquid Ar calorimeter
  - High current, ion built up in the gap, boiling of LAr
    - Replacement takes ≥ 14 months
    - New small detector in the very forward region

- Front-end electronics
  - Bandwidth & latency
  - More granularity for trigger decision
  - Full replacement, not an upgrade

MUON DETECTOR

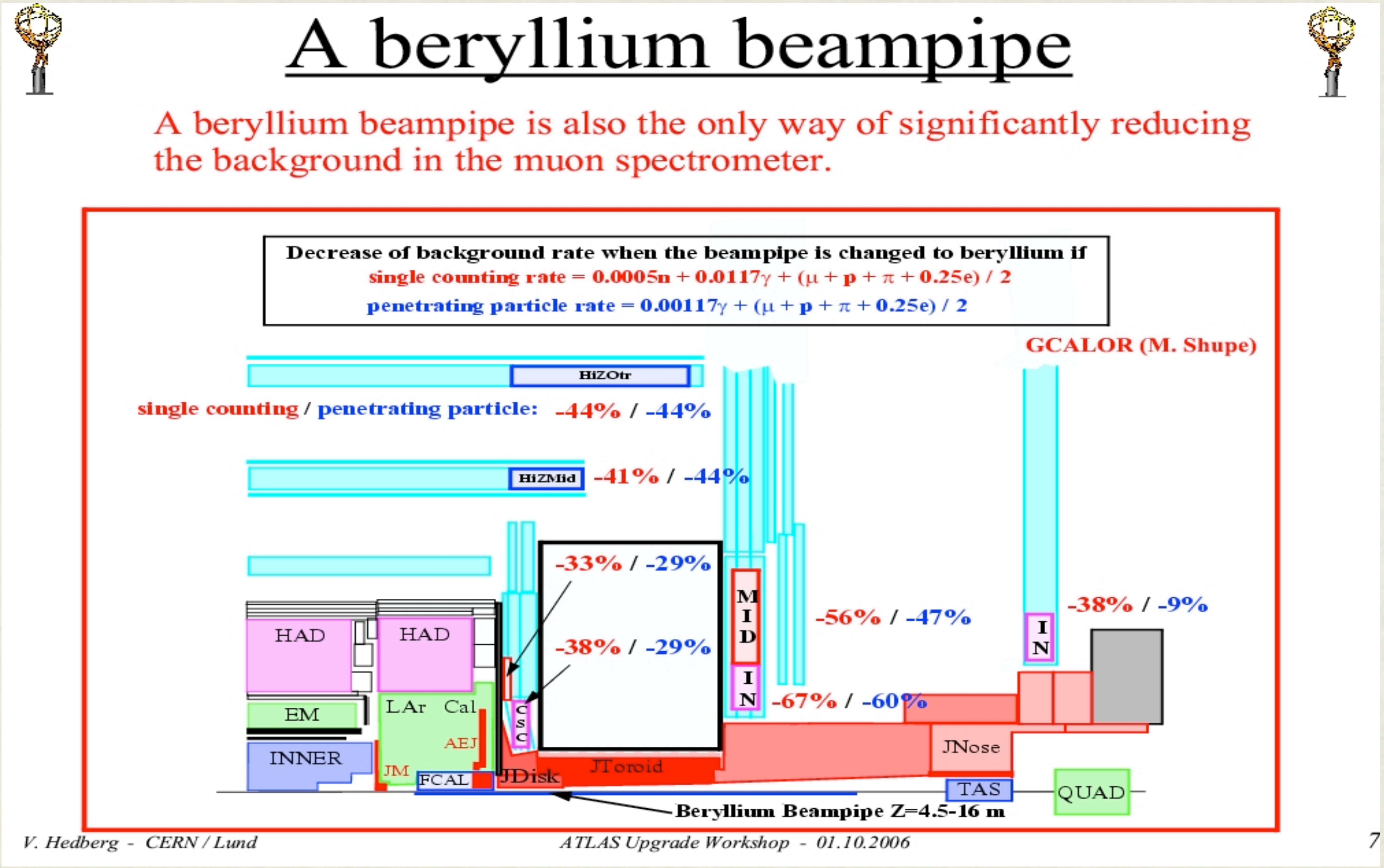
- We don't know the background level yet…
- If background level is as predicted,
  - Only forward chambers need to be replaced
- If background is ×5,
  - Most chambers need to be replaced
- Have to measure background level anyway

- Smaller chamber preferable for more shielding
  - Technology choice
    - Micromegas/thin gap chamber/mini drift tube/etc.

- Redesign of the electronics

BEAM PIPE

- Currently Be near the IP, and stainless steel otherwise
- Stainless Steel part to Be



SUMMARY

- Phase I --- TDR next year (?)
  - 6 to 8 months in 2014 shutdown
    - Pixel sensor survives to 300-400 fb^{-1} (or more)
      - Addition (Replacement) of the innermost layer at ATLAS (CMS), and new beam pipe
- Phase II --- LOI next year (?)
  - 2017-18, possible one year delay
    - Replacement of the whole tracker (ATLAS & CMS)
    - Forward calorimeter
    - Trigger and DAQ
    - Some electronics
    - Forward muon chambers plus the others ?

BACKUP

LHC upgrade stages

"phase 1" ~2013, 2x10^{34} cm^{-2}s^{-1}:

new NbTi triplets, D1, TAS,
β^*~0.25-0.3 m in IP1 & 5,
beam from new Linac4

"phase 2" ~2017, ~10^{35} cm^{-2}s^{-1} :

possibly Nb_3Sn triplet & β^*~0.15 m

+ injector upgrade

complementary measures 2010-2017:

e.g. long-range beam-beam compensation,
crab cavities, advanced collimators, crab waist?
[, coherent e- cooling??, e- lenses??]

phase-2 might be just phase 1 plus complementary measures

longer term (2020?): energy upgrade, LHeC,…

LHC “phase-2” scenarios

- early separation (ES)

  β^*~0.1 m, 25 ns, N_b=1.7x10^{11},
  detector embedded dipoles

- full crab crossing (FCC)

  β^*~0.1 m, 25 ns, N_b=1.7x10^{11},
  local and/or global crab cavities

- large Piwinski angle (LPA)

  β^*~0.25 m, 50 ns, N_b=4.9x10^{11},
  “flat” intense bunches

- low emittance (LE)

  β^*~0.1 m, 25 ns, $\gamma\varepsilon$~1-2 μm, N_b=1.7x10^{11}